MISSISSIPPI RIVER AND TRIBUTARIES
YAZOO BASIN, MISSISSIPPI
BIG SUNFLOWER RIVER MAINTENANCE PROJECT

SUPPLEMENT TO APPENDIX L

WATER QUALITY ISSUES

EXECUTIVE SUMMARY

1. In June 2001, the Mississippi Department of Environmental Quality (DEQ) issued a fish consumption advisory in the Mississippi Delta for DDT and Toxaphene. The DEQ recommended that citizens limit their consumption of fish caught in the lakes and streams of the Delta due to high levels of DDT and its metabolites, DDE and DDD. The purpose of this Environmental Assessment (EA) is to supplement the Supplemental Environmental Impact Statement (SEIS) by addressing some issues that relate to the DDT contamination in the Delta that were not addressed in the SEIS. Those issues are (a) the change in DDT concentration with sediment depth, (b) the potential for the release of DDT from the sediment during dredging, (c) the bioaccumulation and biomagnification potential of DDT, and (d) the risks to aquatic life and human health within the project area with and without dredging. The U.S. Army Corps of Engineers, Vicksburg District, has conducted extensive testing of the sediments and fish tissue to establish baseline conditions and performed elutriate tests to ensure public health and safety would not be adversely impacted by this project. The results of the additional tests are provided in this document. In addition to the testing, the District has conducted a risk assessment to determine the relative risk to the public and to the aquatic environment from two dredging options. The two options are (a) no work and (b) scheduled maintenance dredging as outlined in the 1996 SEIS. The results of the risk assessment are summarized in this document, and the complete report is available as an attachment.

2. Since the SEIS was finalized in 1996, the Corps has collected many sediment core samples from the project area and analyzed them for DDT, DDE and DDD. Collectively these compounds will be referred to as DDX in this EA. Other sampling and analytical procedures have been performed to determine the physical and chemical nature of the sediments and to determine the strength of the chemical bonds that hold the DDX to the sediments. The Corps and other agencies have performed additional fish tissue testing, and those results will be included in this document. In addition, bioassays have been performed to determine the bioaccumulation potential of the DDX and the toxicity of the DDX to benthic organisms.

3. The results of the sediment testing indicate that the concentration of DDX does not significantly vary with sediment depth, although there is a slight trend to have higher DDX concentrations at the mid-depth in the Little Sunflower River. DDX binds very tightly to the sediment and this binding makes much of the DDX unavailable to many organisms, which may explain why so little degradation is observed. The bioaccumulation testing indicates that DDX

does accumulate, but not to toxic levels and the 10-day acute toxicity assay did not indicate any mortality. The risk assessment found that there would be no difference in human health or aquatic environment risk between the no work and the dredging options. In fact, the dredging option indicates a slight reduction in risk during the first several years following dredging.

EXISTING WATER QUALITY

INTRODUCTION

4. This document is intended to address the likely impacts to human health and the aquatic environment due to dredging DDX-contaminated sediments in the Big Sunflower River Basin. This document supplements the Water Quality Appendix from the Big Sunflower River Maintenance Project SEIS.

BACKGROUND INFORMATION

5. This section describes previous assessments of water quality in the project area. The DEQ rates the Big Sunflower River as partially supporting its designations for fish and wildlife propagation and secondary contact recreation. The causes of the partial support are pathogens, pH, and low levels of dissolved oxygen (DO) due to organic enrichment. Low levels of DO can kill fish, but high levels of nutrients are an indirect measure of water quality. High levels of nutrients can cause high algal productivity, which can result in lower levels of dissolved oxygen as the algal cells die.

6. In June 2001, DEQ issued a fish consumption advisory for the Mississippi Delta, which includes the Big Sunflower River Basin. The advisory suggested reduced consumption of certain fish species due to high levels of DDX in fish fillets. Adult consumers are advised to consume no more than two 8-ounce meals of fish from the Delta region per month. Pregnant women and children are restricted to one meal per month. The listed species contained levels of DDX in excess of 1 milligram (mg) per kilogram (kg), but less than 6.0 mg/kg in the edible portions. Fish tissue samples from the Delta have been collected by several Federal and State resource management agencies in the past 6 years. The levels of DDX in fish tissue were generally within the same range for all agencies that collected and analyzed fish tissue samples. Fish tissue pesticide levels are discussed in greater detail in the section on Fish Tissue.

MISSISSIPPI DEPARTMENT OF ENVIRONMENTAL QUALITY

7. The DEQ monitors water quality from stations within the project area. These stations are located on the Big Sunflower River at Sunflower and Anguilla and on Bogue Phalia at Leland and Darlove. The reports that data from both stations on the Big Sunflower indicate that water quality partially supports aquatic life and secondary contact recreation. The water quality data reported at Leland indicate that aquatic life criteria are met but threatened, while data reported at

Darlove are partially supportive of the aquatic life criteria. Partially supported means that 11-25 percent of the observed values for any one criterion are exceeded; or that at least one biological assemblage indicates less than full support with slight to moderate modification of the biological community. These conditions have not changed from what is reported in the SEIS and will not be presented in detail in this document. A complete description of existing water quality can be found in Appendix L, SEIS No. 2.

SEDIMENT QUALITY

OVERVIEW

8. Although sediment quality plays a critical role in the overall health of an aquatic system, there are no nationally accepted criteria for most contaminants. Various criteria have been applied on a regional basis or by states, but none have been applied on a national scale. The Environmental Protection Agency (EPA) has issued sediment criteria for endrin, dieldrin and 3 PAH's in the early 1990s, but none have been issued since. In the absence of any criteria the District is using some benchmarks derived from data collected in the National Status and Trends Program. In March 1990, the U.S. Department of Commerce, National Oceanic and Atmospheric Administration (NOAA), National Ocean Service, Office of Oceanography and Marine Assessment, published Technical Memorandum (NOS OMA 52), "Potential for Biological Effects of Sediment-Sorbed Contaminants Tested in the National Status and Trends Program." This report evaluated the available bioassay data for many contaminants and derived two statistically calculated benchmarks. These benchmarks are referred to as Effects Range-Low (ERL) and Effects Range-Medium (ERM). The ERL is the 10th percentile of the accumulated environmental effects data and represents a low-level benchmark. The ERM represents the 50th percentile of the range of contaminant levels that produce environmental effects. These two benchmarks divide the range of effects into three categories. Sediments with contaminant concentrations less than the ERL represent a minimum effects range in which adverse biological effects would rarely be seen. Sediments with contaminant concentrations greater than the ERL but less than the ERM represent a possible effects range in which effects would occasionally occur. Finally, sediments with contaminant concentrations greater than the ERM represent a probable effects range in which effects would frequently occur. It must be noted that these benchmarks were calculated from bioeffect assays performed on marine organisms, and they may not apply to freshwater systems. The NOAA benchmarks were revised in 1995 (Long et al.) and those values are used in this EA.

SEDIMENT SAMPLING METHODS

9. Surface sediment samples were collected from the project area in 1993 at an approximate frequency of one sample for every 5 miles of river. Additional surface samples were collected in 1995. The surface grab samples were collected with either a petite Ponar sampler or a bucket dredge sampler. The Ponar sampler was used whenever possible, but when it could not penetrate the sediment surface, the bucket dredge was utilized. The Corps collected primarily core

sediment samples from the project area in 1998, 1999, and 2001. The core samples were partitioned into either three or four segments. The upper fraction of the core samples is labeled "top" and represents the same fraction of the material as the surface grab samples. These "top" samples are included with the surface grab samples in the statistical analysis of the data.

10. Sediment core samples were collected from Reach 2 in 1998-1999. Additional core samples were collected from Reaches 1, 2 and 5 in 2001. Core samples could not be collected from some sites due to the high sand content of the sediment. The core sampling device could not capture and retain the sample. When the sand content was high, the material would fall out when extracting the sample from the river bed. The Corps used three different coring devices to collect sediment cores. Dr. Charles Cooper, Agricultural Research Service, National Sedimentation Laboratory, Oxford, Mississippi, designed the first device. It is composed of PVC pipe with both a check valve and a gate valve to prevent loss of the sample. This device collects a 4-foot core. The second device was a 2-inch diameter stainless steel corer composed of individual 1-foot sections. It collects a sediment core up to 5 feet in length. The final device was a 1.5-inch-diameter by 6.5-foot-long stainless steel piston corer. This device was superior to the others in that it allows the collection of an undisturbed core up to 6 feet in depth. This device was used to collect the sediment cores obtained in 2001. All corers were hand-pushed into the sediment until they could not be pushed further. The PVC and the 2-inch stainless steel corers did not collect full core samples, because the depth of the sediment on the outside of the corer did not agree with the length of the sample inside of the device. For example, the January 1999 sample, LS-13, had 4.5 feet of muck on the outside of the sampler, but only 21 inches of sediment on the inside. It was assumed that this corer was able to collect the top 21 inches of sediment before the frictional forces prevented further sample from entering the sampler. After retrieving the sample, it was partitioned into three or four fractions. The earliest cores were partitioned into top, middle and tip fractions. The "top" sample represents the upper 4 inches of each core. The "mid" sample is the middle 4 inches of the core. The "tip" sample was the bottom 2 inches of material in the stainless steel corer. The "tip" sample definitely comes from the bottom of the river, because it was composed of consolidated clay material. The "bot" (bottom) sample is the 4 inches of soft-unconsolidated material above the "tip" fraction or the bottom 4 inches of material from samples without consolidated material in them. The piston corer creates a negative pressure inside the corer to draw the sediment into the corer. Cores obtained with the piston corer showed a change in sediment density increase with sediment depth. Samples collected near the bottom using the piston corer were visibly different in appearance and texture. Laboratory analysis confirmed that the water content of the sediments collected in 2001 decreased with sediment depth.

11. Some sites on the Little Sunflower were also sampled with a mud auger. This allowed a 6- to 12-inch-long sample to be collected from the river bottom, which was labeled auger (aug). This sample was collected through the soft, unconsolidated sediments above the bottom. The soft, unconsolidated material coated the outside of the core as it was pulled back to the top and contaminated the auger samples. The auger samples were rinsed with river water in an attempt to remove the unconsolidated material.

SURFACE SEDIMENT QUALITY

12. The mean and ranges of the surface sediment pesticide concentrations from each reach are provided in Table 1. This table includes all samples collected from 1993 to 2001 by the Corps. The mean DDX ranges from a low of 25 ug/kg in Reach 6 (Big Sunflower) to a high of 370 ug/kg in Reach 9 (Bogue Phalia Cutoff). The overall mean DDX concentration in sediment samples is 98 ug/kg, and the range is 0.95 to 320.9 ug/kg. In sediments, DDE is generally the highest concentration, constituting approximately 69 percent of the ΣDDT. DDD is found in the second highest concentration, making up about 24 percent of the total. DDT makes up the final 7 percent of the ΣDDT in sediments. The observed concentrations of DDE and ΣDDT are compared to the NOAA benchmark screening values in Table 1. The minimum values in all reaches exceed the ERL's for DDE and Sum-DDT. The minimum values exceed the ERM for DDE in Reaches 2, 7, and 8 and the minimums exceed the ERM for Sum-DDT in reaches 3, 7, 8, and 10. The mean values exceed the ERM's for DDE and ΣDDT in all the reaches except Reach 6. The maximum observed values exceed the ERM's in all reaches. This information was used as a screening tool, and the District decided to run sediment bioassays to determine if adverse biological effects would occur. The results of these assays are reported in a later section of this report.

13. The accuracy of the NOAA benchmarks was tested in a study published in 1995 (Long, et al.). The study evaluated the incidence of biological effects to the benchmarks. The authors used four criteria to evaluate the reliability of the benchmarks. Those criteria are (a) the benchmarks agreed closely with the results of other studies (within factors of 3.0 or less); (b) the incidence of effects was low (<25 percent) in the minimal effects ranges; (c) the incidence of effects increased consistently and markedly in concordance with increasing chemical concentrations; and (d) the incidence of effects was very high (>75 percent) in the probable effects ranges. Most of the ERL's and ERM's for the 28 substances that have these benchmarks passed the above criteria. There were some substances that passed one or two of the criteria, but failed to pass all of them. DDE and Sum-DDT failed to pass the last two. The percent incidences of effect within the three test ranges for DDE and Sum-DDT were 5, 50, 50 and 20, 75, 53.6, respectively. The authors expressed less confidence in these benchmarks due to their failure to pass all of the criteria. The four test criteria were also applied to the nine trace metals that had sufficient data to derive benchmarks. Again most of the benchmarks passed all four tests. The incidence of effects for all metals was less than 10 percent for sediments with concentrations less than the ERL's. The incidences of effects increased markedly through the three ranges for all metals except nickel. The incidence of effects was not always greater than 75 percent for the probable effects range. The incidence of effects was between 60 and 70 percent for arsenic, cadmium and zinc, but it was less than 50 percent for mercury (42.3) and nickel (16.9). The authors expressed less confidence in the benchmarks for mercury and nickel due to the low incidence of effects in the probable effects range.

14. In addition to surface sediment pesticide samples, the Corps has collected 21 soil samples from agricultural fields and 4 samples from forested sites in the project area. The soil samples have mean DDX of 611.2 ug/kg and a range of 15.3 to 2,700 ug/kg, while the forest soils have a

mean of 15.9 ug/kg and a range of undetected to 36.4 ug/kg. In contrast to the sediment samples, the concentration of DDT in ag-soil samples is greater than that of DDE. In ag-soil samples DDT makes up approximately 50 percent of the total DDX, DDE makes up approximately 45 percent, while DDD makes up the final 5 percent of the DDX. The high concentration of DDT in the ag-soil samples is an indication of the stability of DDT in an aerobic environment exposed to direct ultraviolet (UV) radiation.

SEDIMENT CORE QUALITY

15. The variation of pesticide concentration with sediment depth is one of the major issues raised by the opponents to this project. Neither the 1999 set nor the 2001 set of samples from the Little Sunflower showed significant differences in pesticide concentration with sediment depth. The 1999 cores indicate a slight tendency for higher total DDT concentration with depth, while the 2001 samples consistently indicate that the mid-depth samples have the highest concentration. Because the older stainless steel corer was unable to obtain a complete core, its bottom samples likely correspond in depth to the mid-depth samples of the 2001 cores. Thus, the sediment layer located approximately 2 feet below the sediment surface may contain somewhat higher levels of DDX.

16. In the 2001 sediment cores the concentration of DDT generally decreases with sediment depth, indicating that some degradation is taking place in the anaerobic environment within the sediment. In contrast, the concentrations of DDD and DDE are higher in the deeper samples than the surface sample. With the maximum values generally appearing in the mid-depth sample. The combination of higher concentrations of DDD and DDE in the deeper sediments and the lower concentrations of DDT may indicate that some transformation of DDT into DDE and DDD is occurring. According to Howard (1991) the half-life of DDT, DDE and DDD in ag-soil is 15.6 years, but the half-life in anaerobic waters ranges from 100 days for DDT and DDE to 294 days for DDD. Based on these rates most of the DDX should be gone from the deep sediment samples; however, this is obviously not true. The persistence of DDX in the anaerobic sediments indicates that it may not be bio-available to microorganisms for degradation.

17. Deep sediment layers were found in the Little Sunflower and the Big Bend region of the Big Sunflower. Both of these areas receive little flow during the summer and fall months and are obviously depositional environments for a good portion of each year. The samples obtained from the Big Sunflower River immediately upstream and downstream of the Holly Bluff cutoff are surface samples due to the nature of the sediment in those areas, which are influenced by the sustained flows.

18. The concentrations of the DDT compounds with sediment depth are displayed in Figures 1a and 1b. The 1999 samples are displayed in Figure 1a, and the 2001 samples are displayed in Figure 1b. One of the first things that should be evident is the great variation in pesticide concentration between samples. There is less variation within the surface samples than within

the deeper core samples. Among the 1999 core samples (Figure 1a), the maximum pesticide concentration increases with increasing depth, but the minimum concentration decreases with depth. Thus, the range in pesticide concentration increases with depth. The greatest variability in pesticide concentration is found in the tip and the auger samples. The highest observed concentration is in a tip sample, but the third and fourth lowest concentrations are also found in tip samples. Auger samples have the lowest observed concentrations and the second highest observed concentration. The 2001 samples (Figure 1b) display a similar trend of increased variability with depth, but the highest concentrations are found in the mid-depth core samples.

19. An analysis of variance (ANOVA) procedure was utilized on the sediment core data to determine if there were any significant differences with sediment depth. The 1999 data were analyzed to determine if there were significant differences with depth or with the sample matrix. The 2001 data were only analyzed to determine if there were significant differences with depth. Finally, all of the sediment core data and the soil samples were analyzed to determine if there were significant differences with core depth and sample matrix. All of the ANOVA's gave similar results. The analyses consistently indicated no significant differences in pesticide concentration with sediment depth. However, there were significant differences in pesticide concentration between the sediment and forest soil samples and the agricultural soil samples. The results of the ANOVA are shown in Table 2. The ANOVA of the 1999 core data found no significant differences with sediment depth, but the analysis of depth and matrix indicated that the ag-soil samples were significantly higher than the forest soils and all of the sediment positions. The ANOVA of the 2001 Little Sunflower cores found no significant differences with depth. The ANOVA of all 2001 cores found that the surface samples were significantly lower in pesticide concentration than the other depths, but three of the "top" sediment samples from the Big Sunflower were composed primarily of sand.

20. In summary, the sediments of the Big Sunflower system are contaminated with DDX at concentrations which are environmentally significant. The observed sediment pesticide concentrations vary considerably with location and depth, and this variation likely affected the results of the ANOVA, which determined that there are no significant differences in pesticide concentration with depth. The concentrations in most locations exceed the NOAA ERM benchmark, which means that the pesticide concentrations are in the "probable" effects range. These benchmarks are, however, found to be relatively weak predictors of bio-effects. In order to assess the magnitude of sediment toxicity, further testing was performed. The results of that testing will be described in the following section of this report.

SEDIMENT CHARACTERIZATION AND TOXICITY TESTS

21. To gain a more complete understanding of the nature of the sediments in the Big Sunflower Basin and the stability of the binding of the pesticides to the sediments, the District sponsored testing at the U.S. Army Engineer Research and Development Center in Vicksburg. The

following tests were performed as part of this research effort: chemical analysis, x-ray diffraction analysis, thermal probe desorption, phospholipid fatty acid (PLFA) and deoxyribonucleic acid (DNA) analysis, bioaccumulation and toxicity bioassays, and Tenex bead desorption analysis. A brief review of the research follows. The complete text with references can be found in the attached supplemental report.

X-RAY DIFFRACTION

22. The results of the chemical analysis were reported in the sediment core section above. The x-ray diffraction analysis determined that the major component of the sediments was Silica dioxide (SiO2) as quartz. The next greatest fraction was the smectite (montmorillonite - swelling clays). Other clays such as illite and kaolinite were present in smaller amounts. The smectites may play an important role in the binding and the inaccessibility of DDT to microorganisms for degradation.

THERMAL PROBE DESORPTION

23. Thermal probe desorption is a relatively new technique that has previously been applied to contaminated sediments in order to determine a compounds bonding strength or the likelihood that it will be released or bioavailable (Talley, 2000). Sediment samples are placed in a small glass vial and inserted into a mass spectrometer. The receptacle is slowly heated to 400 degrees C. As the probe is heated, the compounds in the sample are vaporized and passed into the mass spectrometer for analysis. An increased strength of binding of the contaminant to the soil sample is indicated by a longer retention time (a higher temperature of desorption). An increased temperature of release may indicate a compound that is less bio-available. In these tests, purified DDD, DDE and DDT were spiked onto different surfaces to test the thermal desorption properties of those surfaces. The surfaces used were the glass vial, sand, and kaolin. Agricultural soil from the basin and Little Sunflower River sediments were also tested. The mass spectra for DDD, DDE and DDT are shown in Figure 2. Mass peaks 318 and 246 are characteristic of DDE, while mass peak 235 is characteristic of DDD and DDT. Those three masses were selected to monitor the release of the DDX components. The specific ion chromatograms for DDX spiked on the various surfaces are presented in Figures 3 through 7. These figures show that the desorption time for DDE increases from the glass vial through the kaolin. They also indicate that the relative abundance of DDE mass ions to DDD and DDT increases through the analyses.

24. The selective ion chromatograms for unspiked agricultural soil and unspiked Little Sunflower sediments are presented in Figures 6 and 7. These differ from the ion chromatograms of the spiked samples in that many more peaks are present. These additional peaks represent other organic compounds present in the soil and sediment. The 246-mass ion has a relative abundance of 20 percent in the ag-soil sample and 5 percent in the Little Sunflower sediment sample.

PLFA and DNA

25. The sediments of the Big Sunflower River system are contaminated with DDT and its metabolites. The degradation of DDT is a microbial mediated process. The intent of these experiments was to determine the biomass of the microbial community in the Little Sunflower sediments and whether those bacteria contain the genes necessary to degrade aromatic hydrocarbons such as DDT. PLFA analysis has been used to assess microbial communities for 20 years (White and Ringelberg, 1998). This technique provides a quantitative measure of viable microbial biomass, but does not provide any information on the ability of the bacteria to degrade DDT. Therefore, the microbial DNA in the sediment was analyzed to determine the presence or absence of 11 common degradative gene sequences.

26. The total lipid fractions were extracted from the Little Sunflower River sediment samples and separated into nonpolar, glycolipid and polar lipid fractions using solid phase extraction columns. The polar lipid fraction was methylated and the resulting phospholipid fatty acid methyl esters (PLFAME) were analyzed on a GC/MS equipped with a capillary column. The peaks were detected, quantified and identified using a mass selective detector. Areas under the peaks were converted to concentrations that were normalized to the gram weight extracted for biomass determinations.

27. The total microbial biomass of the Little Sunflower sediment fractions was calculated and is presented in Table 3. The top core sample had the highest biomass of the three sediment fractions. This is typical of sediments. Normally the cell biomass is highest in the surface fraction and diminishes considerably after 1 meter in depth. The total cells per gram dry-weight (cells/gdw) are within the normally observed range of 10^7 to 10^{10} bacterial cells/gdw. In addition to microbial biomass, PLFA analysis can indicate the types of bacteria that are present. The PLFAME analysis provides a quantitative survey of the fatty acid chains present in the microbial community. The length and side chains of the fatty acids are indicative of the types of bacteria present. The results indicate that bacteria with 16-carbon fatty acids dominate the microbial community. These fatty acids are commonly associated with gram-negative bacteria.

28. The analysis of microbial DNA was accomplished using a polymerase chain reaction (PCR) approach. This approach is designed to determine the multiple numbers of biodegradative gene copies present in a single sample. Gene sequences are typically selected for their relationship to a particular biodegradation pathway or toward a general assessment of multiple biodegradative pathways. The presence of a catabolic gene sequence in a DNA extract does not indicate the gene is being expressed, but indicates that the biodegradation potential exists (Langworthy, 1998). Recent studies showed phenotype and genetic potential of the extant microbiota can be used to assess the intrinsic biodegradative potential of the sediment (Tally, 2000).

29. The Little Sunflower River sediment samples were analyzed for the numbers of copies of genes related to the biodegradation of DDT by using a multiplex PCR approach. Eleven genes were examined in the PCR assay. Total DNA was isolated from a seeded soil into a final volume of 50 micro-liters (µl). Multiplex PCR reactions were performed using one µl of sediment DNA extract, or an equivalent of 10-mg sediment per analysis (Ringelberg et al., 2001). A gene was considered detectable if it was present in two of three replicate soil samples.

30. Co-metabolism of the DDT metabolite DDE has been demonstrated in a biphenyl degrading bacteria. Detection of these genes in sediment was used to suggest potential of DDE degradation (Hay and Focht, 1998; Aislabie et al., 1999). DNA was isolated from all three Little Sunflower River sediment samples in amounts consistent with the 10^8 cells/gdw sediment levels derived from the PLFAME data. Even after repeated DNA extraction and amplification attempts, no PCR products for any of the targeted contaminant degradation genes were detected. Positive controls for the extraction and amplification procedures were positive. The gene for sulfite reductases (i.e., bacterial sulfate reduction) was the only gene detectable from the samples. Considering the microbial biomass present in the sediment, multiple copies of the degradative genes should be present if DDT degradation was occurring. Therefore, the potential of these sediments to degrade DDT is low. The absence of these genes may indicate that the DDT present in the sediments is not bio-available. A more detailed description and analysis of these microbial assays is available in the attached supplemental paper on DDT characterization and toxicity.

SEDIMENT DESORPTION KINETICS ANALYSIS

31. This section will present and discuss the results of DDX desorption kinetics experiments on the Little Sunflower and agricultural soil. These experiments address the ease of DDX release from contaminated sediment and soil to a non-polar solid, that has similar surface characteristics to lipid tissues in aquatic organisms. Thus, these experiments address the availability of the bound DDX to aquatic life.

32. Water treatment plants have been using solid absorbents to remove organic contaminants for 25 years. These adsorbents are used to remove contaminants like PCB's, PAH's, and organochlorine pesticides such as DDX. Considerable research has been performed to determine the ultimate fate of nonpolar contaminants bound to adsorbent surfaces such as activated carbon. In this experiment the nonpolar adsorbent is mixed with a suspension of sediment and water. The rates of desorption and absorption are taken as indications of the availability of DDX. A faster rate of desorption would indicate a contaminant that is more available than a slower desorping one.

33. Tenax resin/bead was used as the absorbent in these experiments because its use is well documented and understood. Sediment core samples were obtained from several locations along the Little Sunflower River in the project area. This material was composited and mixed.

Deionized-distilled water was used to make the sediment slurry. Ten grams of sediment were mixed with 0.2 g of Tenax and deionized-distilled water in 50 ml test tubes. The test tubes were rotated for 2 weeks, except during periodic sampling. During sampling the Tenax was removed and replaced. The Tenax beads were then extracted with hexane and the cumulative concentration of DDX is plotted versus time in Figure 8. The relative availabilities of DDD, DDE and DDT are well illustrated by this figure. DDE desorps more readily than either DDD or DDT and it is found in the highest concentration in most fish samples. DDT desorps more slowly than the other contaminants from Little Sunflower sediment and is generally found in the lowest concentration in fish tissue.

SEDIMENT TOXICITY BIOASSAY

34. The purpose of this section is to describe and document the sediment bioaccumulation and toxicity studies performed on Little Sunflower River sediment samples. The results of the assays will be used to predict the potential for bioaccumulation and toxicity of DDX to freshwater organisms in the project area. These tests were performed using EPA recommended procedures utilizing freshwater organisms. The test methodology followed recommendations from the EPA (2000) guidance document "Methods for Measuring the Toxicity and Bioaccumulation of Sediment-associated Contaminants with Freshwater Invertebrates" (EPA/600/R-99/064). Tissue samples collected at the end of the bioaccumulation test were analyzed for contaminants. The tissue-contaminant levels were used to calculate Biota-Sediment Accumulation Factors (BSAF's) for all contaminants present.

35. The test sediment was collected from the Little Sunflower River in March 2001. Control sediment was collected from Brown's Lake in Vicksburg, Mississippi, in the spring of 2001. *Lumbriculus variegatus (L. variegatus)* was used in the 28-day bioaccumulation assay and *Hyalella azteca (H. azteca)* was used in the 10-day toxicity assay. A reference toxicant test was set up concurrent to each test to evaluate the health of the test organism and suitability of the test conditions.

36. The EPA (2000) *L. variegates* 28-day bioaccumulation test for sediments (Test Method 100.3) was used to investigate organochlorine bioaccumulation from the Little Sunflower River sediment. Three replicates of each sediment site were used due to the limited quantity of Little Sunflower River sediment. Tests were conducted under flow-through conditions in box aquaria. Test and control sediments were added to each aquarium to achieve a final sediment thickness of 2.5 centimeters. At the start of the bioaccumulation test, organisms equaling 1 gram of wet tissue were added to each chamber. Dissolved oxygen and temperature were monitored daily. Water chemistry was monitored at the beginning and the end of the test period. After 28 days, test sediments were sieved to recover the worms. Surviving worms were then dried, weighed and frozen for chemical and lipid analysis. Body residue analysis was used to calculate BSAF's for nonpolar organic contaminants present in animal tissue and sediment.

37. Brown's Lake and Little Sunflower River sediment DDX concentrations are listed in Table 4. Table 5 lists the concentrations of DDX in *L. variegatus* from the bioaccumulation assay. The percent survival and the length of *H. Azteca* for the control and test groups are presented in Table 6. The calculated BSAFs for DDX are presented in Table 7. BSAF values for DDX from other bioassays are presented in Table 8 for comparison. The BSAF's calculated with the data from this bioassay are somewhat higher than previously reported, but most of the previous data are from marine environments. Although the BSAFs' are somewhat higher, the total amount of DDX accumulated is less than the previously reported lethal residues that cause 50 percent mortality (LR_{50}). The LR_{50} values calculated from sediment exposure to DDT are presented in Table 9, while the LR_{50} values calculated from water exposure are listed in Table 10. The final observed DDX tissue values are considerably lower than the LR_{50} values and toxicity from DDX to benthic organisms is not expected. Using the BSAF and the LR_{50} for DDT from Table 10, a sediment concentration that would induce 50 percent mortality can be calculated. The resulting value of 807 µg/kg is 12 times higher than the highest observed sediment concentration in the Big Sunflower Basin. The sediment concentrations for DDD and DDE that would induce 50 percent mortality in organisms are 3,650 and 11,600 µg/kg, respectively. All of these values are 12 to 32 times greater than the highest observed concentrations of those compounds in the Big Sunflower Basin. The value is three orders of magnitude greater than the ERM for DDE, which is primarily based on co-occurrence assays.

38. The second bioassay performed using Little Sunflower River sediment was the 10-day acute toxicity test using *H. azteca.* Mean survival in the 10-day assay for test organisms was 86.2 percent. The mean survival for control organisms was 95 percent. Mean survival in the both the control groups and the test groups exceeded the minimum required for an acceptable test (80 percent). There were no significant differences in survival between the test and control sediments ($p=0.183$). Organism length at the end of the exposure period was used as an indicator of growth. Mean length of the organisms exposed to Little Sunflower and Brown's Lake sediments were 2.24 and 2.17, respectively. No significant differences in length were observed ($p=0.598$). The toxicity of DDT to *H. azteca* has been previously investigated using spiked sediments (Lotufo et al., 2001). The 10-day LC_{50} for DDT was 1,097 µg/kg (885-1,133; 95 percent confidence interval) or 182,833 µg DDT/kg organic carbon (147,500-188,833; 95 percent confidence interval). Due to the low concentration of DDX in the Little Sunflower sediments, low toxicity was expected.

FISH TISSUE QUALITY

39. The examination of fish tissue is one of the best means to determine if contaminants present in sediment or the water column are available to aquatic life. Extensive fish tissue sampling has occurred in the Yazoo Basin during the last 8 years. The Corps, the DEQ, the Yazoo-Mississippi Joint Water Management District (YMD) and the U.S. Geological Survey (USGS) have all collected fish tissue samples within the Yazoo Basin in the last 8 years. The Corps collected samples in 1993, 1995, and 2001. The DEQ collects samples annually. YMD collected samples

in 1993, 1995, and 1997. The USGS collected samples in 1995 and 1998 as part of the Mississippi Embayment-National Water Quality Assessment. The Corps has compiled all of these data into a single database for analysis. Also included are other historical fish tissue data that were collected by these and other agencies. The Corps and the DEQ collected fillet samples from several species of fish. YMD collected mainly fillet data, but also processed some whole fish samples from several species. The USGS collected only whole fish samples from Carp.

40. The fish tissue concentrations of samples collected in the Big Sunflower River Basin over the past 30 years are displayed in Figure 9. The values are plotted by water body. The figure illustrates that fish tissue levels have been observed over a wide range of values for most of the period. At first look, it may appear that fish tissue concentrations are increasing, but this is likely due to the increased number of samples and species collected. Figure 10 shows the same data plotted by river mile and fish species. It shows that the observed concentrations vary considerably over the project area and within each species of fish. Figure 11 shows the data normalized by lipid (fat) concentration. Pesticide concentrations are normalized by the percent lipid concentration as a means to reduce the inter-species differences in pesticide concentration due to the natural differences in lipid concentrations between species. The lipid-normalized data show a much narrower range of values. The blue catfish from mile 38 have a range of values of near 0.0 to 15.0 mg/kg (Figure 10), while the normalized concentrations are all less than 4.0 mg/kg. Species such as blue catfish, which have high lipid concentrations, may appear to have higher pesticide concentrations due to the greater amount of lipids. Hydrophobic contaminants like DDT are generally stored in an organism's fatty tissues, such as in the skin and internal organs. Muscle tissue generally is lower in fat and may not contain high levels of contaminants. Lipid normalization is used in the risk assessment and in the determination of the biota-sediment accumulation factors discussed later in this EA. Mean fish tissue concentrations for eight species of fish are listed in Table 11. The means for DDX range from 1.71 to 4.4 mg/kg. These means are all in excess of the 1.00 mg/kg lower limit for fish consumption advisories, but less than the 6.0 mg/kg upper limit for nonconsumption.

ELUTRIATE TESTING

41. The Corps and the EPA jointly developed the elutriate test to simulate dredging activities in the laboratory and provide a measure of the likely impacts to the water column resulting from dredging activities. There are two versions of the test, the standard and the modified elutriate test. The standard elutriate test is used to predict the release of contaminants into the water column resulting from open water disposal. The standard test uses four parts water to one part sediment, followed by 30 minutes of mixing. After mixing, the suspended solids are allowed to settle and the supernatant water is centrifuged and tested for dissolved contaminants. The modified test is used when the discharge passes through an upland containment area before returning to the water body. The modified elutriate test uses a 10 to 1 ratio of water to sediment. The sample is mixed for one hour and allowed to settle for 24 hours before the supernatant water is removed for analysis. The suspended materials are separated by filtration and the filtrate is

tested for contaminants. The concentrations of contaminants in the elutriate samples are compared to their concentrations in the upstream water. When the contaminant concentrations increase, their concentration in the discharge zone after mixing is compared to the aquatic life criteria.

42. The District has performed both tests on sediment samples from the project area. Three standard elutriate tests were performed in 1995, six modified elutriate tests were performed in triplicate in 1994, and two more were performed in triplicate in 2001. The results of the pesticide and metals analyses of the four associated sample matrices (upstream water, sediment, total elutriate water, and filtered elutriate water) are found in Tables 10a and 10b. The total number of analyses whose results were greater than the method detection limit is presented as a ratio to the total number of analyses completed. The upstream water and the filtered elutriate water are the two sets of data that need to be compared to each other and the aquatic life criteria presented in the right column as Freshwater Chronic Criteria and Freshwater Acute Criteria. The other two sets of data are for information only. The aquatic life criteria do not apply to the unfiltered elutriate water or the sediment data.

43. Chlorinated pesticides are infrequently detected in the upstream water or the filtered elutriate samples. In Table 10a, only the parameters with concentrations greater than the detection limit for any of the four matrices were included. Within this subset, parameters with all results reported as less than the method detection limit are marked with 'ND' for not detected. Again, the number of samples with results greater than the detection limit are presented in the table as a ratio to the number of tests completed. A combined total of nine chlorinated pesticides were detected in the three water matrices and the sediment, but only four were detected in the upstream water and the filtered elutriate samples. DDT was detected in one upstream water sample out of 15. This sample exceeded the freshwater chronic criteria. DDT was not detected in the corresponding filtered elutriate water sample. Endrin showed the same pattern. Two out of 15 samples had concentrations greater than the detection limit and above the aquatic life criteria. For two parameters, DDD and DDE, the upstream water had no samples with concentrations greater than the detection limit. For both of these parameters, six of the filtered elutriate water samples had concentrations greater than their method detection limits, although none exceeded their aquatic life criteria and therefore dilution in the containment area effluent is not required.

44. Although not a primary focus of this study, the elutriate samples were also analyzed for trace metals. The results of the trace metals analyses are presented in Table 10b. The mean trace metals concentration in the filtered elutriate samples exceeded the concentrations in the upstream water for chromium, copper, lead, nickel, selenium, and zinc; however, the differences are generally small, suggesting that resuspension concentrations will be minimized. The mean values for lead, mercury, and silver exceeded the aquatic life criteria in both the filtered elutriate and the upstream water. Data maxima for cadmium, copper, lead, mercury, silver, and zinc exceeded the aquatic life criteria for both the filtered elutriate and the upstream water. Mercury was the only metal whose mean, minimum, and maximum values for all tests exceeded the aquatic life criteria. However, the mean concentration in the filtered elutriate sample decreased

an order of magnitude from the upstream water concentration. Mean filtered elutriate water concentrations decreased for three other metals--arsenic, cadmium, and silver.

45. The results from the filtered elutriate tests showed that no water quality criteria for pesticides were exceeded in any of the tests. These tests conclusively indicate that dredging will not increase the dissolved levels of DDT in the Big Sunflower River Basin during dredging.

COMPARATIVE ECOLOGICAL AND HUMAN HEALTH RISK ASSESSMENT

46. Menzie-Cura & Associates, Inc. of Chelmsford, Massachusetts, were commissioned to perform an ecological and human heath risk assessment for the Corps of Engineers Big Sunflower River Maintenance Project (BSRMP). The risk assessment utilized, measured, and estimated concentrations of DDT, DDD, and DDE (DDX) in sediment, water, soil, and fish tissue to address the potential aquatic ecological and human health effects from exposures to these chemicals originating from sediments of the Big Sunflower River Basin. The assessment estimated and compared potential exposure and risks in the Big Sunflower River Basin under two general long-term conditions of approximately 40 years. The conditions were (a) no work conditions that used measured concentrations in sediment and water, for the initial year, and modeled concentrations for all subsequent years, and (b) dredging conditions that used measured concentrations in sediment and modeled concentrations in water for the initial year (during which the dredging actively occurs) and modeled sediment and water concentrations in all subsequent years.

47. The Corps provided the risk assessors with existing sediment, water, and fish tissue data from samples collected in 1993–1995, 1997, and 2000. The project area includes ten areas or "Items of work." The assessment addressed only seven items because work in Item 3 is complete, Item 9 is scheduled for only clearing and snagging, and Item 4 is scheduled for mostly clearing and snagging.

CONCEPTUAL MODEL

48. The conceptual model developed for the risk assessment integrated existing information describing the humans and wildlife species that may use the Big Sunflower River Basin, the potential fate and transport mechanisms for DDX, and potential routes of exposure for humans and ecological receptors. The model assumed that the source of contaminants changes with dredging alternatives and activities. The no-work condition assumed that the aquatic environment was the primary source of DDX to which people or organisms might be exposed. During dredging, the disposal locations would also become potential contaminant sources in addition to the aquatic environment. Following dredging, the terrestrial environment (soil runoff from upland soil, dewatered dredged material disposed on land, or soil mixed with dredged material) was the primary source of contaminants. The assessment did not address terrestrial exposure.

49. The human receptors for the model were anglers and subsistence fishermen. Ecological receptors were selected from species most likely to encounter DDX in the Big Sunflower River Basin within a sediment-based food web. They included a reasonable cross-section of the major functional and structural components of the ecosystem. The ecological receptors selected included local warmwater fish (mosquito fish – a forage fish, smallmouth buffalo fish – a bottom dwelling fish, blue catfish – a predatory fish, flathead catfish – a piscivorous fish, shortnose gar – a water column fish); osprey – a piscivorous bird; mallard duck – a waterfowl-consuming benthic invertebrates and plants; and mink – a predator mammal consuming fish and invertebrates.

50. The EPA describes an assessment endpoint as an explicit expression of the actual environmental value to be protected. The environmental risk assessment endpoints for the BSRMP could not be measured directly in advance of dredging. Therefore, the endpoints selected were endpoints that are measurable biological responses to DDX. These measurement endpoints were used to make inferences about the assessment endpoint. The first assessment endpoint was the sustainability of warm water fish in the Big Sunflower River Basin. Measurement endpoints were (a) the sustainability of a benthic macro-invertebrate community serving as a food source as represented by modeled body burdens of DDX in representative benthic invertebrates, and (b) modeled and measured body burdens of DDX in selected fish species as a measure of exposure and effects. The second assessment endpoint was the survival, growth, and reproduction of local populations of aquatic wildlife as represented by the osprey, mallard duck, and mink. This survival rate was measured by modeling the dose of DDX in sediment, surface water, invertebrates, and warm water fish for use in evaluating exposure via the food chain.

PREDICTED ENVIRONMENTAL CONCENTRATIONS

51. The risk assessment extended the qualitative descriptions of exposure pathways in the conceptual model to calculate quantitative estimates of the exposure of selected receptors to DDX in sediment, water and biota. Predicted concentrations of DDX in sediment, water and biota were used to calculate body burdens in fish and invertebrates based on a bioaccumulation model, the FISHRAND model. A simple food chain model used these predicted body burdens and the predicted sediment and water concentrations from the fate and transport models to return doses of each compound or doses of the sum of two or more compounds to higher order predators.

52. The specific exposures for each of the seven items and the two conditions included (a) concentrations of DDX in sediment as 40 years of annual average concentrations for the no dredging and dredging conditions, (b) concentrations of DDX dissolved in surface water as a single value that does not change over time for the no dredging and dredging conditions, (c) concentrations of DDX in whole surface water for use in the drinking water pathway, (d) the sum DDX body burden concentrations for the representative fish species, aquatic plants, and

aquatic invertebrates both individually and bioaccumulativly, (e) doses of the sum DDX through the food chain to the mallard, osprey, and mink based on modeled sediment, surface water, benthic invertebrate, and aquatic plant and fish concentrations using a simple food chain model, (f) doses of DDE through the food chain to the mallard and osprey based on modeled sediment, surface water, benthic invertebrate, aquatic plant, and fish concentrations using a simple food chain model, and (g) doses of the ΣDDT through the food chain to mink based on modeled sediment, surface water, benthic invertebrate, aquatic plant, and fish concentrations using a simple food chain model.

ESTIMATED ECOLOGICAL RISKS

53. The fate and transport models used existing data to estimate and project sediment and surface water DDX concentrations for the 40-year life of the project. These models showed that the incremental contribution of remobilization of bottom sediment during dredging is less than 5 percent, and typically within 1 or 2 percent of existing resuspension concentrations. Additionally, the model showed that the predicted freely dissolved water concentrations are within a few percent of water concentrations under current conditions and that the sediment and water concentrations during dredging are effectively no different than current concentrations.

54. For the assessment endpoint, sustainability of warm water fish, the risk assessment indicated that generally there is no potential risk to the fish community in Items 1, 2, 5, 6, 7, and 10, based on the measurement endpoints, invertebrate body burdens and fish body burdens of DDX under either the no work or dredging conditions. For Item 8, there is potential for risk to the fish community based on the measurement endpoints, body burdens in invertebrates and body burdens in all modeled fish species. The dredging conditions did not alter the potential risk in Item 8.

55. For the assessment endpoint, survival, growth, and reproduction of local populations of aquatic birds and mammals, the risk assessment indicated that there is potential risk to wildlife in Items 1, 6, 7, 8, and 10 based on the measurement endpoint, doses of DDX to osprey. There is potential risk to wildlife in all items based on the measurement endpoint, doses of DDX to mallard duck. The predicted dredging conditions ameliorate this risk in Item 6 for osprey and in Item 2 for the mallard duck. Results show that there is no potential risk to mammals, as represented by the mink, in any of the Items under either condition.

56. For all endpoints, the risk comparison between the no dredging and dredging conditions indicates that after about 10 to 15 years, the risks tend to level off into what is thought to be steady state risk under the given conditions.

ESTIMATED HUMAN HEALTH RISKS

57. The human health exposure assessment estimated the magnitude of actual and potential human exposure to DDX, the frequency and duration of these exposures, and the pathways by which people are potentially exposed under these conditions. Two levels of exposure were evaluated--reasonable maximum exposure, a value that is unlikely to underestimate actual exposure; and central tendency exposure, an estimation of the average exposure of any given individual. The assessment does not predict risks to actual individuals who use the project area, but estimates potential risks based on types of behaviors and assumptions about those behaviors. To minimize uncertainty, information specific to the Mississippi Delta was incorporated into the model whenever possible. Particularly helpful were the data from a survey on fish and wild game consumption patterns in the delta region of Mississippi, conducted in the summer of 2001 by Dr. Dennis A. Frate of the University of Mississippi Medical Center. The use of region-specific fish ingestion rates based on Dr. Frate's survey rather than rates from the general population or another geographic region reduced uncertainty in the estimates of absolute risk.

58. The exposure scenario evaluated was an angler who consumes fish caught in the rivers in the project area for the first 15 to 45 years of his life (age 1 to 16 or 46) under the no dredging and dredging conditions. The human risk assessment also evaluated a 1-year, subchronic exposure to a young child (2 to 3 years old) who does not go fishing, but consumes the fish that his parents catch under no dredging and dredging conditions.

59. The human health risk assessment showed that generally there is potential for risk to anglers consuming fish from the rivers in the Big Sunflower River Basin and that the risks are essentially the same with or without the dredging project. Specifically, estimates of hazard and risk vary among project items by about a factor of ten, depending on assumptions made about fish tissue concentrations. Estimates of hazard and risk vary within an item by about a factor of ten, depending on assumptions made about fish ingestion rates and characteristics of people who consume fish. Results from models of both the noncancer hazard and the cancer risk suggest that residents of this region may experience significant levels of risk for cancer and noncancer health effects with or without the planned dredging activities.

SOURCES OF UNCERTAINTY

60. Any risk characterization is subject to uncertainties since it combines the potential uncertainties in the data, exposure assumptions, and toxicity estimates. Each of these areas has sources of uncertainty that may lead to overestimating or underestimating risk. The Big Sunflower River Basin risk assessment characterized the range of potential values when data permitted. When data were not available, conservative assumptions in keeping the EPA default values were applied.

61. Sources of uncertainty in this assessment, including those associated with surface water, sediment, and fish tissue concentration estimates, affect absolute estimates of risk for each item, but have less effect on estimates of relative risk between dredging and no dredging conditions because the uncertainties apply equally to each condition.

SUMMARY OF WATER QUALITY FINDINGS

62. Surface water in the Big Sunflower Basin suffers from an excess of nutrients and suspended sediment, and experiences periods of low levels of dissolved oxygen and periods of high levels of pathogens. The river sediments of the basin are contaminated with DDX. The DDX bioaccumulates in benthic organisms and biomagnifies up the food chain. Fish tissue pesticide levels exceed DEQ risk levels leading to a fish consumption advisory issued in the summer of 2001. Sediment bioassays do not indicate that the sediments are toxic or have an adverse effect on invertebrate growth. Elutriate testing indicated that dredging would not induce an increase in dissolved pesticide levels. A risk assessment was performed to assess the likely impacts to human health and to the aquatic environment as a result of maintenance dredging. The risk assessment found that there was no difference between current conditions and with-project conditions with regard to human health or the aquatic environment. The risk assessment did find that the near future condition would be slightly improved under the future with-project condition.

REFERENCES

(to be provided later)

	N	DDD	DDE	DDT	SUM DDT
Reach 1, Big Sunflower River, Mile (6.9-33.5)					
Mean	14	26.9	**34.3**	10.2	**71.4**
Min		2.4	**2.3**	0	6.1
Max		80.0	**97.8**	30.0	**168.4**
Reach 2, Little Sunflower River, Mile (7.0-20.5)					
Mean	32	21.1	**58.2**	7.2	**86.6**
Min		12.3	**27.9**	1.1	**42.8**
Max		37.0	**180.0**	35.2	**226.6**
Reach 3, Little Sunflower River, (20.5-27.7)					
Mean	2	25.5	**42.5**	14.0	**82.0**
Min		14.0	**25.0**	12.0	**51.0**
Max		37.0	**60.0**	16.0	**113.0**
Reach 4, Holly Bluff Cutoff Mile (19.2-26.1)					
Mean	5	28.0	**50.1**	22.8	**101.0**
Min		1.5	**2.8**	2.8	**7.1**
Max		50.3	**85.7**	59.2	**167.8**
Reach 5, Big Sunflower River, Mile (28.4-50.2)					
Mean	5	37.5	**29.8**	8.7	**75.9**
Min		10.0	**4.3**	1.3	**20.4**
Max		93.8	**60.0**	20.0	**120.0**
Reach 6, Big Sunflower River, Mile (50.2-70.6)					
Mean	4	8.6	**9.5**	6.9	**25.0**
Min		2.6	**2.5**	2.3	**7.9**
Max		15.0	**23.0**	19.0	**57.0**
Reach 7, Bogue Phalia, Mile (1.0-7.1)					
Mean	4	46.5	**80.5**	23.2	**150.2**
Min		27.0	**42.0**	6.2	**78.6**
Max		74.0	**166.0**	65.0	**305.0**
Reach 8, Bogue Phalia, Mile (7.1-19.8)					
Mean	2	84.5	**190.0**	10.4	**284.9**
Min		29.0	**80.0**	6.8	**123.0**
Max		140.0	**300.0**	14.0	**446.8**
Reach 9, Bogue Phalia, Mile (19.8-24.2) & (0.0 12.4)					
Mean	3	142.8	**202.6**	25.3	**370.6**
Min		8.4	**7.7**	3.8	**19.9**
Max		280.0	**360.0**	50.0	**550.0**
Reach 10, Big Sunflower River, Mile (7.06-75.6)					
Mean	2	31.5	**38.0**	33.3	**102.8**
Min		21.0	**25.0**	9.6	**55.6**
Max		42.0	**51.0**	57.0	**150.0**

Table 1, Sediment Pesticide Concentrations by Reach

DDE ERL=2.2 µg/kg, ERM=27 µg/kg;

Sum DDT ERL 1.58 µg/kg, ERM 46.1 µg/kg;

Values in **Bold** >ERL, Values in **Bold** > ERM

Table 2, Analysis of Variance of DDX with Sediment Depth and Sample Matrix

Group Mean # Mat	Group Mean # Mat	Group Mean # Mat	Group Mean # Mat
DDD 1999 All Samples by Matrix Pr>F=0.0118 A 0.0520 21 Ag B 0.0282 99 Sed B 0.00315 4 For	DDE 1999 All Samples by Matrix Pr>F=0.0001 A 0.243 21 Ag B 0.0628 99 Sed C 0.00846 4 For	DDT 1999 All Samples by Matrix Pr>F=0.0001 A 0.316 21 Ag B 0.00457 99 Sed B 0.00426 4 For	ΣDDT 1999 All Samples by Matrix Pr>F=0.0001 A 0.611 21 Ag B 0.0955 99 Sed B 0.0159 4 For
DDD 2001 L. Sunflower Core Samples Pr>F=0.2145 A 0.0518 5 Mid A 0.0505 5 Bot A 0.0234 5 Top	DDE 2001 L. Sunflower Core Samples Pr>F=0.3992 A 0.159 5 Mid A 0.122 5 Bot A 0.099 5 Top	DDT 2001 L. Sunflower Core Samples Pr>F=0.1298 A 0.010 5 Top A 0.006 5 Mid A 0.001 5 Bot	ΣDDT 2001 L. Sunflower Core Samples Pr>F=0.3779 A 0.215 5 Mid A 0.171 5 Bot A 0.132 5 Top
DDD 2001 All Core Samples Pr>F=0.0052 A 0.051 9 Bot A 0.051 9 Mid B 0.020 14 Top	DDE 2001 All Core Samples Pr>F=0.0097 A 0.140 9 Mid A 0.113 9 Bot B 0.058 14 Top	DDT 2001 All Core Samples Pr>F=0.3212 A 0.0117 9 Mid A 0.0078 9 Bot A 0.0050 14 Top	ΣDDT 2001 All Core Samples Pr>F=0.0064 A 0.201 9 Mid A 0.167 9 Bot B 0.085 14 Top
DDD All Samples By Matrix and Depth Pr>F=0.0009 A 0.061 22 Ag AB 0.043 19 Tip AB 0.043 21 Bot AB 0.034 6 Com AB 0.032 30 Mid AB 0.022 20 Aug AB 0.019 35 Top B 0.002 4 For	DDE All Samples By Matrix and Depth Pr>F=0.0001 A 0.269 22 Ag B 0.098 21 Bot B 0.087 30 Mid B 0.078 19 Tip B 0.059 6 Com B 0.055 35 Top B 0.042 20 Aug B 0.008 4 For	DDT All Samples By Matrix and Depth Pr>F=0.0001 A 0.346 22 Ag B 0.008 30 Mid B 0.006 35 Top B 0.005 21 Bot B 0.004 19 Tip B 0.004 4 For B 0.0026 20 Aug B 0.0022 6 Com	ΣDDT All Samples By Matrix and Depth Pr>F=0.0001 A 0.676 22 Ag B 0.145 21 Bot B 0.127 30 Mid B 0.125 19 Tip B 0.095 6 Com B 0.079 35 Top B 0.066 20 Aug B 0.011 4 For

Table 3 Biomass of Microorganisms in Little Sunflower River Sediment			
Sample	**Location**	**pmoles PLFA/gdw**	**Cells x 10^6/gdw**
A	Top of Core	8,421	168.4
B	Middle of Core	3,164	63.3
C	Bottom of Core	5,063	101.3

Table 4 Little Sunflower Composite Sediment Concentrations (µg/kg dry weight)				
Replicate	**DDT**	**DDD**	**DDE**	***DDT**
1	12.9	32.2	74.8	119.9
2	17.4	38.2	85.2	140.8
3	18.5	39.1	83.2	140.8
Mean	16.3	36.5	81.1	133.8
Standard deviation	3.0	3.8	5.5	12.1
Brown's Lake Sediment Concentrations (ug/kg dry weight)				
	<2.92	<2.92	<2.92	<2.92

Table 5

Tissue Concentrations of DDT, DDD, DDE and *DDT in *L. Variegatus* (µg/kg wet weight)

Sediment Type	Replicate	DDT	DDD	DDE	DDX
Little Sunflower River	1	8.9	98.3	548.0	665.2
	2	12.5	144.0	784.0	940.5
	3	7.4	60.2	402.0	469.6
	Mean	9.6	100.8	578.0	668.4
	Standard deviation	2.6	42.0	192.8	237.2
Brown's Lake	1	<5.03	<5.03	10.1	20.2
	2	<5.03	<5.03	10.8	20.9
	3	<5.03	<5.03	12.5	22.6
	Mean	<5.03	<5.03	11.1	21.2
	Standard deviation	<5.00-	<5.00-	1.2	<5.00-

Table 6

Percent Survival And Length Of *H. Azteca* Following 10-Day Toxicity Experiment

Sediment Type	Replicate	Percent Survival	Mean ± 1 SD length (mm)
Little Sunflower River	1	50	2.28±0.38
	2	100	2.15±0.31
	3	100	2.61±0.45
	4	80	2.11±0.34
	5	80	2.21±0.18
	6	90	1.91±0.18
	7	100	2.14±0.39
	8	90	2.47±0.27
	Mean	86	2.24
	Standard deviation	17	0.26
Brown's Lake	1	90	1.66±0.35
	2	100	2.47±0.07
	3	100	2.09±0.10
	4	90	2.09±0.25
	5	100	2.32±0.34
	6	90	2.01±0.26
	7	90	2.37±0.19
	8	100	2.35±0.56
	Mean	95	2.17
	Standard deviation	5	0.22

Table 7

Little Sunflower River Sediment and Mean Tissue Concentrations of DDT, DDD , DDE, *DDT, and BSAF for *L. variegatus*

Parameter	Sediment Concentration (µg/kg)		Tissue Concentration (µg/ kg)		BSAF
	Dry wt	Organic Carbon	Wet wt	Lipids	
DDT	16.3	1,479.1	9.6	1,299	0.88
DDD	36.5	3,318.2	100.8	13,626	4.11
DDE	81.1	7,370.0	578.0	78,108	10.6
*DDT	133.8	12,167.3	668.4	93,032	7.65

Table 8 BSAF Values for DDT and DDE For Aquatic Invertebrates				
Species	**Sediment Contamination**	**Compound**	**BSAF**	**Reference**
Estuarine amphipod *Leptocheirus plumulosus*	Spiked	DDT	2.88	Lotufo et al. 2001b
Freshwater amphipod *Hyalella azteca*	Spiked	DDT	0.76 - 2.13	Lotufo et al. 2001a
Freshwater amphipod *Diporeia* spp.	Spiked	DDT	0.07 - 0.56	Lotufo et al. 2001a
Marine amphipod *Rephoxinius abronius*	Field-collected	DDT	0.09	Meador et al. 1997
Marine bilvalve *Macoma nasuta*	Field-collected	DDT	0.05	Boese et al. 1997
Marine bilvalve *Macoma nasuta*	Field-collected	DDT	0.14	Rubinstein 1994
Marine polychaete *Hetermastus filiformis*	Spiked	DDT	0.4 - 0.8	Mulsow and Landrum 1995
Marine polychaete *Armandia brevis*[C]	Field-collected	DDT	0.2	Meador et al. 1997
Marine polychaete *Nereis virens*	Field-collected	DDT	0.14	Rubinstein 1994
Marine bilvalve *Macoma nasuta*	Field-collected	DDE	0.65 - 2.8	Ferraro et al. 1990
Marine bilvalve *Macoma nasuta*	Field-collected	DDE	0.07	Rubinstein 1994
Marine polychaete *Nereis virens*	Field-collected	DDE	0.48	Rubinstein 1994

Table 9

LR_{50} Values For *DDT In Benthic Invertebrates Derived From Sediment Exposures

Species	LR_{50} (µg/kg wet wt)	Reference
Marine polychaete *Neanthes arenaceodentata*	>141,600	Lotufo et al. 2000b
Estuarine copepod *Schizopera knabeni*	>425,000	Lotufo (unpublished)
Freshwater oligochaete *Tubifex tubifex*	>754,000	Lotufo (unpublished)
Marine amphipod *Leptocheirus plumulosus*	2,690	Lotufo et al. 2001b
Freshwater amphipod *Diporeia* spp.	5,947	Lotufo et al. 2001a
Freshwater amphipod *Hyalella azteca*	2,620	Lotufo et al. 2001a

Table 10

LR_{50} Values For DDT, DDD, And DDE In Benthic Invertebrates Derived From Water Exposures (Lotufo et al. 2000a)

Species	Compound	LR_{50} (µg/kg wet wt)
Hyalella azteca	DDT	710
	DDD	15,000
	DDE	123,700
Diporeia spp.	DDT	15,600
	DDD	84,200
	DDE	477,000

Table 10a, Chlorinated Pesticide Elutriate Results

Parameter Mean Min Max n > DL / total n	Upstream Water ug/l ppb	Filtered Elutriate ug/l ppb	Total Elutriate ug/l ppb	Sediment mg/kg ppm	Aquatic Life Criteria FWC [1] FWA [2] ppb
DDD	 ND 0/15	0.032 0.017 0.036 6/20	0.086 0.036 0.270 6/19	30.5 4.1 101. 11/11	0.600 --
DDE	 ND 0/15	0.042 0.013 0.150 6/20	0.209 0.013 1.04 12/19	47.7 2.9 166. 11/11	-- 1050.
DDT	**0.039** **0.016** **0.059** 1/15	 ND 0/20	**0.056** **0.040** **0.120** 6/19	10.5 0.85 65.0 10/11	0.001 1.1
Heptachlor	 ND 0/15	 ND 0/20	 ND 0/19	0.64 0.40 1.10 1/11	0.0038 0.52
Endosulfan	 ND 0/15	 ND 0/20	0.031 0.007 **0.170** 3/19	19.8 0.26 150. 3/11	0.056 0.22
Endosulfan Sulfate	 ND 0/15	 ND 0/20	0.023 0.013 0.190 1/19	0.84 0.53 1.39 1/11	-- --
Endrin	**0.178** **0.016** **<u>0.218</u>** 2/15	 ND 0/20	 ND 0/19	 ND 0/11	0.0023 0.18
Endrin Aldehyde	 ND 0/15	 ND 0/20	 ND 0/19	2.34 0.76 14.0 1/11	-- --
Heptachlor Epoxide	 ND 0/15	 ND 0/20	**0.058** **0.016** **0.076** 2/19	 ND 0/11	0.0038 0.52

[1] Numbers in bold type exceed the Freshwater Chronic Criteria.
[2] Underlined numbers exceed the Freshwater Acute Criteria.

Table 10b, Trace Metal Elutriate Results

Parameter Mean Min Max n > DL / total n	Upstream Water ug/l ppb	Filtered Elutriate ug/l ppb	Total Elutriate ug/l ppb	Sediment mg/kg ppm	Aquatic Life Criteria FWC [1] FWA [2] ppb
Arsenic	6.9 0.6 10.3 12/12	4.2 1.3 7.0 10/12	113. 2.3 **412.** 12/12	6.7 3.1 10.8 8/8	190 360
Cadmium [3]	0.5 0.2 **2.4** 4/12	0.3 0.1 **0.7** 8/12	**4.2** 0.2 **13.5** 10/12	0.3 0.06 0.6 8/8	0.66 15.4
Chromium [3]	3.2 1.0 15.0 4/12	4.7 0.7 12.0 6/12	**261.** 1.7 **1070.** 12/12	14.8 4.9 34.7 8/8	120 980
Copper [3]	4.6 2.1 **14.0** 12/12	6.4 1.4 **15.0** 12/12	**205**. 3.7 **655.** 12/12	14.2 1.4 36.5 8/8	7.1 9.9
Lead [3]	**1.8** 0.6 **6.0** 8/12	**2.4** 0.6 **6.0** 7/12	**202**. 0.7 **706.** 11/12	14.9 5.0 31.3 8/8	1.3 34
Mercury	**0.4** **0.02** **1.6** 7/12	**0.042** **0.012** **0.134** 9/12	**0.68** **0.13** **1.70** 12/12	0.188 0.067 0.290 6/8	0.012 2.4
Nickel [3]	3.5 1.0 11.0 10/12	4.5 0.7 9.0 11/12	**179.** 3.1 **624.** 12/12	16.8 7.7 31.6 8/8	88 790
Selenium	ND 0/12	1.4 1.3 2.0 1/12	**8.0** 1.3 **23.0** 6/12	0.2 0.1 0.6 3/8	5.0 20
Silver [3]	**4.2** 1.0 **10.0** 2/12	**3.0** 0.7 **6.7** 6/12	**6.0** 0.7 **13.4** 6/12	ND 0/8	-- 1.23
Thallium	ND 0/12	ND 0/12	3.9 1.3 12.0 6/12	0.2 0.1 0.2 3/8	-- --
Zinc [3]	23.2 7.0 **99.0** 5/12	48.3 4.7 **118.** 9/12	**1025.** 14.0 **3390.** 12/12	62.6 14.3 130. 8/8	59 65

[1] Numbers in bold type exceed the Freshwater Chronic Criteria.
[2] Underlined numbers exceed the Freshwater Acute Criteria.
[3] Criteria based on mean hardness of 50 mg/l as calcium carbonate.

Table 11, Mean Fish Tissue DDX Concentration by Species

	N	DDD	DDE	DDT	SUM DDT
Bigmouth Buffalo					
Mean	12	0.448	0.936	0.330	1.497
Min		0.038	0.167	0.021	0.277
Max		1.220	4.370	1.650	7.240
Blue Catfish					
Mean	29	0.981	2.185	0.371	3.051
Min		0.050	0.190	0.002	0
Max		5.300	7.300	2.100	14.860
Channel Catfish					
Mean	50	0.522	1.116	0.318	1.943
Min		0.020	0.070	0.010	0.120
Max		2.900	5.400	1.490	9.350
Common Carp					
Mean	7	0.726	3.629	0.177	3.309
Min		0.370	1.200	0.005	0.180
Max		1.100	5.500	0.520	6.915
Flathead Catfish					
Mean	20	0.513	1.402	0.194	2.038
Min		0.030	0.080	0.010	0.110
Max		1.700	4.000	0.660	6.410
Paddlefish					
Mean	5	0.838	1.376	0.193	2.407
Min		0.290	0.520	0.055	0.865
Max		1.390	2.280	0.300	3.960
Shortnose Gar					
Mean	10	1.155	2.874	0.389	4.190
Min		0.291	0.790	0.054	1.410
Max		3.130	7.350	0.990	11.130
Smallmouth Buffalo					
Mean	14	0.689	1.853	0.337	2.374
Min		0.048	0.230	0.011	0.210
Max		2.910	7.830	1.630	12.370

MISSISSIPPI RIVER AND TRIBUTARIES
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SUPPLEMENT TO APPENDIX L

WATER QUALITY ISSUES

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